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WATER DYNAMICS OF TOURIGA-NACIONAL GRAPEVINES TRAINED TO SPUR PRUNED CORDON AND GUYOT SYSTEMS UNDER MEDITERRANEAN CLIMATE CONDITIONS

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Abstract

Aims: The aims of the present study were to (1) evaluate the water dynamics of Touriga-Nacional grapevines trained to spur pruned cordon and Guyot systems and (2) assess the effect of variable water availability in a commercial vineyard located in the Demarcated Douro Region (DDR), Portugal.

Methods and Results: The study was carried out in a commercial vineyard, located in the Upper Douro sub-region (the eastern sub-region with harsher climatic conditions) of the DDR. The climate of this area is typically Mediterranean and the soil of schist origin. Touriga-Nacional grapevines grafted onto 110 Richter rootstocks trained to spur pruned cordon and Guyot systems were selected. Sap flow and trunk diameter measurements were performed during the growing season. Complementarily, soil moisture, leaf water potential and leaf area index measurements were made. The results showed daily trunk diameter fluctuations (TDFs), with the contraction, recovery and increment phases and higher sap flow (SF) rates at earlier stage. Under harsh pedoclimatic conditions, SF was reduced and TDF flattened. Rehydration and stomatal mechanisms were mostly associated with these responses. Furthermore, Guyot-trained vines showed higher changes in TDF for the same SF values, where TDF of spur pruned cordon-vines remained practically unchanged over maturation. These results pointed to the effect of the shorter length of the hydraulic pathways of the Guyot-trained vines, in comparison with the cordon-trained vines.

Conclusions: The study exposed the daily and seasonal water dynamics and crop performance of mature vines over the growing season, highlighting the adaptive potential of the Guyot training system to the DDR. The use of plant-based measurement sensors (sap flow and trunk diameter sensors) revealed sensitivity to irrigation (and precipitation) events and conditions of significant atmospheric evaporative demand.

Significance and Impact of the Study: Adaptation strategies to climate variability and climate change must be adopted to maintain grapevine yield and quality in order to guarantee economic and environmental sustainability. The adequate selection of the grapevine training system and improved water-use efficiency stand out as one of the most critical for the present and future times.

Keywords: Douro Demarcated Region, sap flow, training system, trunk diameter variation, *Vitis vinifera*

Introduction

Vitis vinifera is a major crop in the Douro Demarcated Region (DDR, NE Portugal), constituting an important source of income for local farmers. Grapevines are strongly influenced by the hot and dry local climate, which invariably induces water deficits in the upper soil profile, especially during summer (Ferreira *et al.*, 2012). Furthermore, this region is likely to face a greater and intensified number of abiotic events in the near future (Santos *et al.*, 2020).

Grapevines can control their water status by developing strategies to cope with critical conditions of high atmospheric evaporative demand and low soil water availability, such as stomatal control (Ferreira *et al.*, 2012). Nevertheless, adaptation strategies involving cultural practices must be adopted to guarantee economic, social and environmental sustainability. One major adaptation strategy is the selection of the grapevine training system (Van Leeuwen *et al.*, 2009). The spur pruned cordon is currently the most widely used training system in the DDR. However, a training system with a lower trunk, such as the Guyot system may bring advantages in hot and dry areas such as the DDR (Magalhães, 2015).

Since the development of the pressure chamber (Scholander *et al.*, 1965), water relations in grapevines have been extensively investigated. However, more easily automated techniques have also been used such as sap flow and trunk diameter variations (Fernández, 2017).

Therefore, the objectives of the present study were to (1) evaluate the water dynamics of Touriga-Nacional grapevines trained to spur pruned cordon and Guyot systems and (2) assess the effect of variable water availability in a commercial vineyard located in the DDR, Portugal.

Material and Methods

The study was undertaken during the 2017-growing season in a commercial vineyard, located in the DDR (41°04'18'' N, 7°04'51'' W, 160 m). The climate is of the Mediterranean type characterized by very irregular rainfall distribution throughout the year, with most falling during the winter months and very little during the summer. In this region, long-term annual rainfall is about 580 mm. Corresponding annual mean minimum and maximum temperatures are 10.0 ^{o}C and 19.8 ^{o}C, respectively.

Vitis vinifera L. Touriga-Nacional vines grafted onto 110 Richter rootstocks were planted in 2011 at a vertical (30% slope) spacing of 2.2 × 1.0 m (4545 vines ha^{-1}), with E-W orientation. Two training systems were defined: unilateral (single) spur pruned cordon (trunk height of about 0.6 m) and single Guyot (trunk height of about 0.4 m) systems with similar numbers of buds (eight) left at winter pruning. The soil, affected by human activity, is essentially of schist origin with a loam dominated texture. The vineyard was managed, according to the grower's commercial cultural practices. To prevent plant death, around 6-mm events of water (during maturation), totaling 50 mm, were provided.

Trunk diameter fluctuations (TDF) were determined using linear variable differential transformers (LVDT). Six sensors were installed, divided by both training systems, which had been previously calibrated. The thermal dissipation technique (Granier, 1985) was used to evaluate the sap flow of spur pruned cordon and Guyot-trained vines over the growing season. Additional information regarding weather, soil moisture, predawn leaf water potential and leaf area index measurements can be found in Malheiro *et al.* (2020).

Results and Discussion

The 2017 growing season stood out, with low precipitation and high temperatures. The mean temperature for the April-August (April-October) period was 23.4°C (22.6°C). The total annual precipitation was 320 mm, of which 25% was observed during the growing season. Despite the water provided by irrigation and precipitation that caused occasional increases in soil moisture and in predawn leaf water potential, these variables globally diminished over the growing season, though no significant differences were found between training systems (data not shown).

In terms of plant water dynamics, Figure 1A–D show the daily courses of SF and TDF values during two intervals: post-flowering (Figure 1A, C), and ripening (Figure 1B, D). Generally, both variables exhibited higher values at the earlier interval, decreasing in the following, being clearer in the TDF values (Figure 1). During the first interval (Figure 1A, C), corresponding to a moderate plant water stress period, daily SF displayed a typical bell-shaped

curve that increased markedly from sunrise until noon, falling to negligible values at the end of the day. These SF maximums became lower over the ripening period (Figure 1B, D). This reduction in SF rates reflected the progressive soil water depletion and enhanced atmospheric demand, as well as the decrease in total leaf area by the onset of senescence towards the harvest period. LAI increased until about veraison and, then started to decline over maturation. No significant LAI differences were found between training systems (data not shown). During the first interval, daily fluctuations of trunk diameter (TDF) clearly exhibited three phases: recovery, increment and contraction (Figure 1A, C). In the following period (Figure 1B, D), there was a reduction in TDF, with only partial recovery during the night as a reflection of low water availability and high evaporative demand (Fernández, 2017). This phenomenon was a result of stomatal control in response to lower water availability (Escalona *et al.*, 2002) and higher irradiance and VPD, revealing a key survival strategy of vines under water stress conditions (Ferreira *et al.*, 2012). Under these atmospheric conditions, irrigation was able to slightly sustain or even increase SF (Figure 1) but for a short period. TDF was also found to be sensitive to water supply in grapevines (Santesteban *et al.*, 2015), revealing a small increase in the increment of the trunk but tending to lose these values between irrigation events in our study. Interestingly, daily TDF responded earlier and more visibly than SF during an irrigation event. This finding is in agreement with the results reported by Fernández *et al.* (2011) in olive trees.

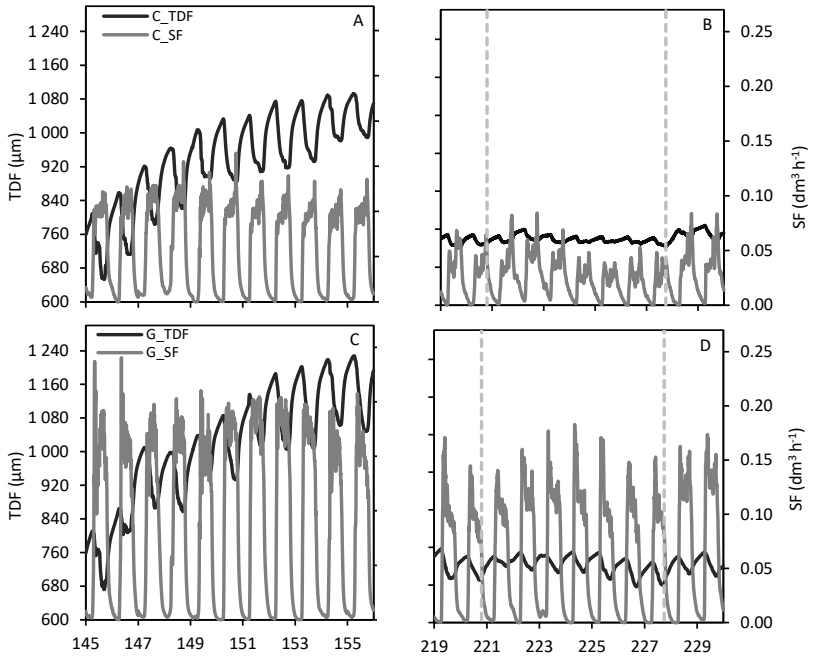

Figure 1: Time courses (over days of the year) of sap flow (SF) and trunk diameter fluctuation (TDF) in Touriga-Nacional grapevines trained to spur pruned cordon (C) system for post-flowering (A), and maturation to (B). Similarly, for Guyot (G) trained vines (C and D). The dashed lines indicate an irrigation event.

Regarding the training systems, the Guyot-trained vines showed higher maximum SF values compared with the spur pruned cordon-trained vines over the season, indicating greater whole-vine transpiration (Figure 1 and 2). Furthermore, Guyot-trained vines showed higher changes in TDF for the same SF values, where TDF of cordon-vines remained practically unchanged over maturation (e.g. DOY 220; Figure 2). These results could be due mainly to the fact that the Guyot-trained vines have lower trunk height in contrast to the higher trunk and permanent horizontal cordon of spur pruned cordon-trained vines, shortening and facilitating the water pathway along the soil–plant–atmosphere continuum (Schubert *et al.*, 1999).

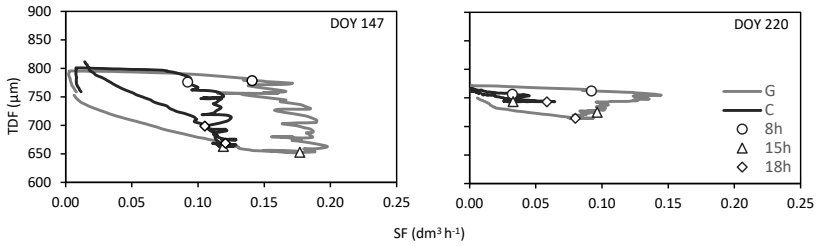

Figure 2: Relationship between daily courses of sap flow (SF) and trunk diameter fluctuation (TDF) of Touriga-Nacional grapevines trained to spur pruned cordon (C) and Guyot (G) systems on two different days of the year (DOY 147 and 220). The values recorded at 8h, 15h and 18h are indicated with symbols.

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